THINK INDIA JOURNAL ISSN: 0971-1260

Vol-22-Issue-17-September-2019

Fog Computing: An Extension To Cloud Computing

Mandeep Kaur

Assistant Professor, School of Computer Science and Engineering, Lovely Professional University, Phagwara, Punjab.

Abstract: Bringing technology to the core of human life could be possible due to few recent technologies. These technologies have made it possible to handle large amounts of data processing requirements, big volume of user requests with heterogenous processing specifications. Cloud Computing and Fog Computing can also be counted under this category of technologies. But many of the stakeholders are still doubtful about which technology should they choose for their needs. This paper is an attempt to clarify such thoughts. In this paper authors have given an introductory review upon basic characteristics of both of these technologies. A comparison is also made on the basis of factors which differentiate these paradigms. This study may be helpful to clarify the considerations of selection of appropriate technology in modern applications.

1. Introduction

Technology is spreading in every corner of our daily lives. Whether it is communication, shopping, health, banking, education or any other significant field of life, technology is everywhere. We are surrounded by numerous applications which serve these daily needs. Every application deal with data. Few applications generate data and few others consume data. The kind of data flow occurring around us is so vast and large in quantity that ordinary consumer devices are not capable to handle it. Meeting high end infrastructural requirements at individual level is almost impossible. Hence distributed systems such as cloud computing or fog computing came into existence. These systems provide low cost infrastructure, without increasing the financial burden upon the consumers. It is two-way gain. At one side it allows the users to take advantage of high capacity infrastructure, without actually purchasing it. On the other hand, it also ensures the sufficient task flow to distributed devices, which is a way of proper utilization of available resources.

In distributed systems, the infrastructure is provided by the separate stakeholders or resource providers. These services are provided on payment basis i.e. every user will be paying to the service providers as per his usage. Services are provided as a utility. With day to day increase in customer crowd even enterprises cloud providers such as Google, Amazon and Microsoft are facing the challenge to meet user requirements.

Similarly, Fog computing is also a distributed system. It is considered as an extension to cloud computing. Cloud data centres provide high capacity infrastructure. But are limited in number. On the other hand, Fog computing nodes are more in number but are comparatively weaker in resource capacity. Motivation behind fog computing is to distribute the jobs in

Copyright © 2019 Authors

local level computing nodes. It helps in reducing latency, network congestion and other challenges.

Fog is not there to compete with cloud, but both of these are associates to achieve a common goal which is to improve the user experience. Fog computing uses the same set of resources which cloud computing has been using. Many of the attributes of cloud computing are adapted by fog computing too.

This paper is aimed at comparing the cloud computing with fog computing and to explore their similarities and differences. Further sections of this paper will go into the depths of both these computing paradigms: Section 2 describes the research work carried out in this field by various authors. Section 3 will present the comparative study of cloud computing vs fog computing. Section 4 will conclude the comparative study of the paper.

2. Related Work

Cloud and fog computing being so similar conceptually confuse the concerned. As these both paradigms work together, it is very much important to distribute proper rules and responsibilities between both of these. For this same purpose it is very much important to understand both the paradigms separately as well as together. This is the objective of current paper. Many of the researchers have presented these concepts in various ways. In 2011, in NIST definition of cloud computing, Peter et al. [1] have discussed about what is cloud computing to how to use in best possible way. In this paper authors have specified the characteristics of cloud computing sating how this amazing paradigm can be used for optimum results. In 2012, Rodolfo et al. [2] have described the importance and sitability of fog computing in IoT environment by demonstrating the role of fog computing in three areas which are Connected Vehicle, Smart Grid, and Wireless Sensor and Actuator Networks. In 2017, Tasnia et al. [3] have proposed a distributed, secure and more efficient infrastructure. In this paper, authors have focused on comparative analysis of fog computing with existing traditional models and infrastructure. Authors have tried to prove the success rate of fog computing to overcome the challenges. In 2018, Faragardi et al. [4] have proposed a time-predictable cloud framework that is capable to handle latency needs of a project. Authors have also suggested a design decision regarding resource requirement to develop a fog platform and the minimum bandwidth required between cloud and fog. In 2017, Vitor et al. [5] suggested a proactive and reactive strategies to handle failure recovery in network elements. They have created a model, Multidimensional Knapsack Problem (MKP) and studied the effect of all these strategies. Obtained results can be useful for analysing the best suitable recovery strategy in IoT scenario. In 2019, Sarang et al. [6] have proposed a decoupled transversal security strategy to handle QoS-Security tradeoff in systems applying cloud-fog together. In 2018, Denis et al. [7] have discussed the impacts of developing information and communication technologies and processing as well as analysis of large amount of data. These impacts are becoming the motivation behind IoT solutions for problems such as increasing bandwidth and data channels. In 2017, Harald et al. [8] have introduced the concept of seamless computing between multi-domain applications. Authors have presented a reference model is introduced involving existing cloud technologies. In 2017, Enzo et al. [9] have proposed a technological paradigm named Fog of Everything (FOE) by integrating Fog Computing paradigm and Internet of Everything. According to

 Copyright © 2019 Authors

authors this integration has increased the opportunities for innovative applications. In 2018, Sumit et al. [10] have presented an analysis of the scalability and performance of edge cloud systems, helpful in supporting latency-sensitive applications. In [11], authors have formulated a QoS aware service allocation problem for Combined-Fog-Cloud (CFC) architecture. According to authors, the solution to this problem will help in reducing latency while respecting the capacity requirements of services. In 2019, Nivedhita et al. [12] have presented a model for IoT service distribution to reduce the amount of service latency and to improve the performance at QoS aspect.

3. Cloud Computing vs Fog Computing

Cloud computing technology is a well-established concept in the industry now. It has spread its roots in almost every field. Fog computing on the other hand is a complement the cloud computing by minimizing the latency related issues. Apart from these there are so many similarities and differences in both the systems. Here we will have a deep dive in these paradigms:

3.1 Cloud Computing

Paradigm of Cloud Computing has made high capacity computing, storage, networks infrastructure available to modern applications. Cloud mechanism provide access to sharable resources through large pools of resources called datacentres. Resources provided by these datacentres are virtualized, scalable and configurable as per the needs. Cloud computing popularized the concept of pay-as-you-go cost model which allows the users to pay as per usage only. This is a great freedom for users with fluctuating needs of computing resources. A user can connect and disconnect from the cloud services as per his need. He does not need to involve service providers for these actions.

There are essential characteristics of cloud computing which state the behaviour of this paradigm towards the users. Most important characteristic is that cloud services are on-demand and self-service based i.e. no provider intervention is required in connecting or disconnecting to the users. Next characteristic is that it provides access to a broad network. Third is about cloud’s capability of resource pooling. This characteristic state the clouds multi-tenant model. Same resource can be used by multiple consumers. Fifth cloud characteristic is about rapid elasticity which defines the scalable nature of cloud services. Fifth characteristic is measured services. Whatever resources a consumer consumes are transparently visible to the consumers as well as provider.

Cloud computing provides various service models. Three basic models are as follows:

SaaS (Software as a Service): As per this model a provider’s application runs on a server and various clients can make use of it. Web based email service is a popular example of this service model.

PaaS (Platform as a Service): Under this service model a consumer created application can be deployed upon the cloud infrastructure. Consumer has the control over application only

Copyright © 2019 Authors

and not upon the deployment infrastructure. Provider may provide languages, libraries, services, and tools for creation of consumer applications.

IaaS (Infrastructure as a Service): In this case client can control the operating system, storage and deployed application. A user can also have some control over the networking components.

With the passing time so many other service models have been introduced such as Storage as a Service, Communication as a Service (CaaS), Monitoring as a Service (MaaS) etc. With the increasing time these types of service models are expected to grow in numbers as well as variety.

Cloud computing also has 4 types of clouds which are: public, private and hybrid. Public clouds are openly accessible. Any user can access a public cloud resources, private cloud is created for a specified group of users. Most of the time this group of users can be the employee of an organization of a student group of an Institute or some similar group. Third type is hybrid which is partially public and partially private.

3.2 Fog Computing

Origin of fog computing lies in the popularity of IOT applications. Use of IOT has drastically increased the data usage as well as data generation from end devices side. IOT applications are most of the times very much latency sensitive. Latency includes one round to and from a cloud server. IOT applications need instant response. This is not possible in case of cloud computing because cloud servers are available in datacentres which can be situated in faraway places from the actual IOT devices.

To manage this latency limitation of cloud computing, another concept called fog computing is introduced. Under fog computing, cloud like services are brought to the edge network. Local provider environments are created which are comparatively nearer to user IOT devices. These nodes create an extra layer between the end user devices and the cloud. All latency sensitive services are now handled by fog layer.

Fog computing has a set of characteristics of its own. Above all, fog computing reduces latency and increases the location awareness of the computing resources. Secondly fog computing establishes a layer between IOT devices and cloud. It does this by adding cloud like resources at local level. Hence it provides a wide-spread geographical distribution. Fog mechanism provides mobility. Fog is a network consisting large number of nodes. It includes vital role of wireless access. There are so many streaming and real time applications in use currently. And last but not the least, heterogeneity of the nodes in fog computing.

Fog computing has reduced the gap between cloud environment and end IoT devices. All the data related activities are performed at both the ends i.e. cloud as well as fog. Main objective of fog computing is to support the IoT mechanism. It provides a flexibility to both, users as well as providers.

3.3 Comparison Factors

Copyright © 2019 Authors

Though it is a well-known fact that cloud and fog computing mechanisms complement to each other. But still there are so many factors which make them different from each other. Following table represents such major factors:

	Fog Computing	**Cloud Computing**
Latency	Fog nodes are placed nearer to user devices. Hence, obviously they have lesser latency as compared to cloud nodes. Though, QOS is also a matter of concern while thinking about the reduced latency.	Cloud nodes are placed at distance from the user devices. Hence, obviously they have more latency as compared to cloud nodes.
Democracy	Fog nodes are pervasive in nature i.e. they are more in count and are wide spread geographically. Fog nodes do not include the high capacity resources as are the cloud datacentres.	Cloud environment is considered more centralized as compared to fog environment. Cloud nodes are centralized. Dedicated datacentres cater to the needs of users. They are geographically distributed but are rich in resources.
User Requirements	Fog nodes can provide more need-oriented services.	Cloud datacentres provide comparatively generic services.
Security	Fog nodes have to think about their security of their own. Fog applications face more security breaches as compared to cloud data centres. Major reason behind this is the independence of fog nodes from each other.	Cloud environment is considered more secured and safer for user data and applications. Cloud environment can maintain the centralized security mechanism, equally enforced upon all the participants.
Role of Nodes	Computational nodes in fog environment can either behave like a client to fog or can behave like the providers in themselves.	Datacentres in cloud environment always play the role of service providers. They are intentionally created to serve the requirements of clients.
Connectivity	In fog computing it is an option. You can work offline and data transfers take place whenever it finds an active connection.	Continuous network connectivity is a must for cloud computing

Table 1: Major factors of comparison between cloud and fog computing

3.4 Cloud Architecture vs Fog Architecture

Cloud and Fog architecture are basically very much similar to each other. In case of cloud computing environment clients sends their data related requirements to the cloud service providers. These requests can be for a particular set of infrastructures, a particular type of

Copyright © 2019 Authors

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

software, being hosted by the service provider any of the service types which are available with cloud provider. User requests are directly submitted to the cloud environment where these are assigned to a datacentre for further processing. Networking devices such as switches, routers etc play a supporting role during this transfer of request and response between client and provider.

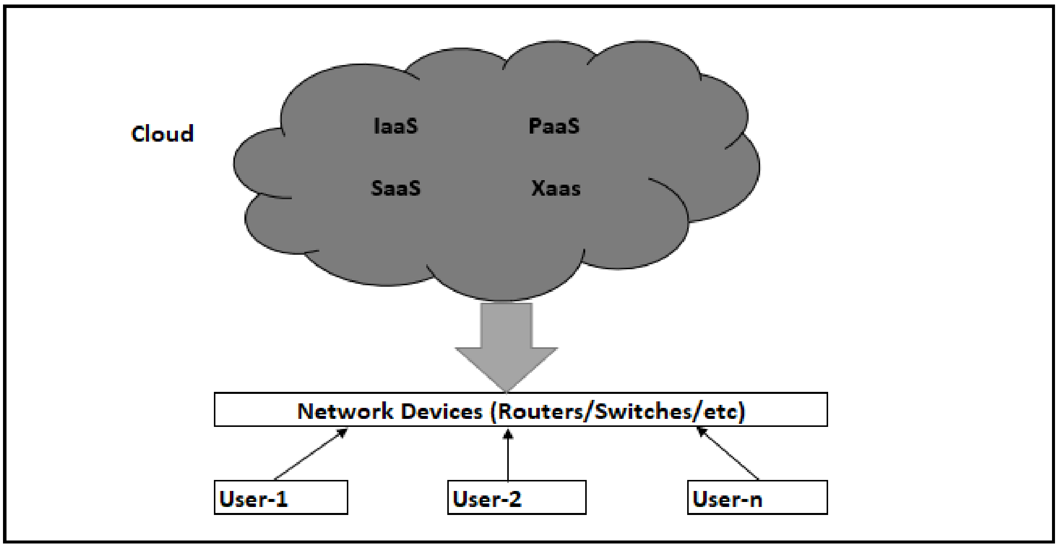

Figure 1: Cloud Computing Architecture

Fog computing architecture on the other hand includes an extra layer known as fog layer. This layer bridges up the gap between IOT devices and cloud environment. Any user submits his request with certain qualitative and quantitative expectations. All these expectations are termed under an agreement known as Service Level Agreement (SLA). Fog computing architecture and the fog layer ensures the efficient and quality enforcement of this agreement. A fog node can be designed to perform any computing tasks which a cloud computing node can perform. Only because of being deployed as a local server, the capacity of resources provided by the fog layer is comparatively lower than cloud computing nodes.

Copyright ⓒ 2019 Authors

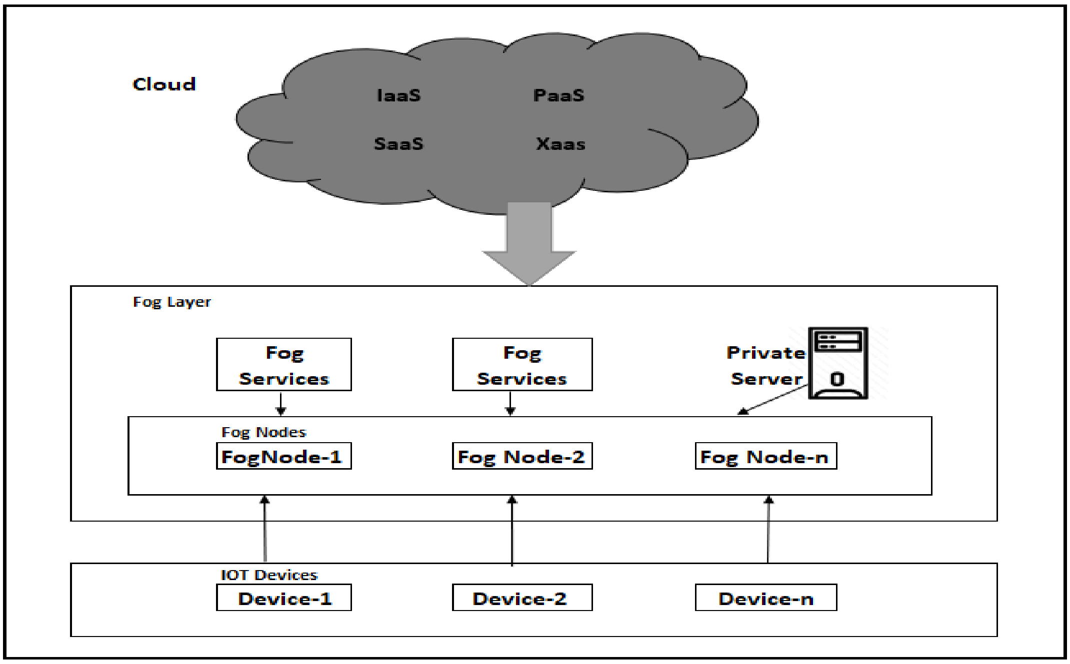

Figure 2: Fog Computing Architecture

In fog computing architecture fog environment listens to the requests submitted by IOT devices and applications. These requests are first handily submitted to the fog layer. Where fog nodes provide fog services to these requests. Every request has to go through fog node before accessing the cloud environment.

As per discussion in this section we have seen than cloud computing and fog computing are just like associates to meet a common goal, that is to provide quality services to the users. We cannot imagine effective output by separating both of these. Fog computing provides the presence of computing resources at various levels and cloud computing provides the required power of resource. Put together, these paradigms have produced amazing results.

4. Conclusion

In this paper, author have tried to compare and clarify the roles of fog computing and cloud computing paradigms. It is to be concluded that these two paradigms are much more powerful in association, than in separation. If fog provides the reduced latency, on the other hand cloud provides the powerful resource capacity. Bringing both these paradigms together can open doors to enormous opportunities in this world of applications. Lots of research opportunities are there to find ways to use these two giant technologies seamlessly in a collaborated environment. There is a need to further search for the parameters and characteristics to balance tradeoff between latency vs quality, so that both these technologies can be exploited in best possible ways.

References

[1] Peter Mell, Timothy Grance, "The NIST Definition of Cloud Computing," *Special Publication 800-*

Copyright ⓒ 2019 Authors

145, 2011.

[2] Flavio Bonomi, Rodolfo Milito, Jiang Zhu, Sateesh Addepalli, "Fog Computing and its Role in the Internet of Things," *Researchgate,* pp. 13-15, 2014.

[3] Tasnia Ashrafi Heya, Sayed Erfan Arefin, Md. Arshad Hossain and Amitabha Chakrabarty, "Comparative Analysis of Computation Models for IoT: Distributed Fog vs. Conventional Cloud," in *Proceedings of the 2017 4th International Conference on Advances in Electrical Engineering (ICAEE)*, Dhaka, 2017.

[4] Tasnia Ashrafi Heya, Sayed Erfan Arefin, Md. Arshad Hossain and Amitabha Chakrabarty, "A Time-Predictable Fog-Integrated Cloud Framework: One Step Forward in the Deployment of a Smart Factory," *Real-Time and Embedded Systems and Technologies (RTEST),* pp. 54-62, 2018.

[5] Vitor Barbosa Souza, Xavi Masip-Bruin, Eva Marin-Tordera, Wilson Ramirez, Sergio Sanchez-Lopez, "Proactive vs Reactive Failure Recovery Assessment in Combined Fog-to-Cloud (F2C) Systems," in *IEEE 22nd International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, 2017.

[6] Sarang Kahvazadeh, Xavi Masip-Bruin, Rodrigo Diaz, Eva Marin-Tordera, Alejandro Jurnet Jordi Garcia, Ana Juan, Ester Simo, "Balancing Security Guarantees vs QoS Provisioning in Combined Fog-to-cloud systems," in *10th IFIP International Conference on New Technologies, Mobility and Security (NTMS)*, 2019.

[7] Denis V. Gadasin, Andrey V. Shvedov, "THE CONCEPT "FOG COMPUTING" - THE EVOLUTIONARY STAGE OF DEVELOPMENT OF INFOCOMMUNICATION TECHNOLOGIES," in *Systems of Signals Generating and Processing in the Field of on Board Communications*, 2018.

[8] Harald Mueller, Spyridon V. Gogouvitis, Andreas Seitz, Bernd Bruegge, "Seamless Computing for Industrial Systems spanning Cloud and Edge," in *International Conference on High Performance Computing & Simulation*, 2017.

[9] Enzo Baccarelli, Paola G. Vinueza Naranjo, Michele Scarpiniti, Mohammad Shojafar, Jemal H. Abawajy, "Fog of Everything: Energy-Efficient Networked Computing Architectures, Research Challenges, and a Case Study," *IEEE Access,* vol. 5, pp. 9882-9910, 2017.

[10] Sumit Maheshwari, Dipankar Raychaudhuri and Ivan Seskar, Francesco Bronzino, "Scalability and Performance Evaluation of Edge Cloud Systems for Latency Constrained Applications," in *Third ACM/IEEE Symposium on Edge Computing*, 2018.

[11] V.B.C.Souza, W.Ramirez, X.Masip-Bruin, E.Marin-Tordera, G.Ren, G.Tashakor, "Handling Service Allocation in Combined Fog-Cloud Scenarios," in *Next-Generation Networking and Internet Symposium*, 2016.

[12] V.Nivedita, N.NandhaGopal, "A Framework of IOT Service Assignment To Mitigate The Service Latency With Collaboration Of Fog and Cloud," in *IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, 2019.

Copyright © 2019 Authors